MINERALOGY OF THE MAFIC ANOMALY AT SOUTH POLE-AITKEN AND IMPLICATIONS FOR MANTLE EXCAVATION

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The detection of a low-albedo mafic anomaly associated with South Pole-Aitken (SPA) Basin by Galileo instruments (1) brought new hope to the quest for identifying (and perhaps later collecting) lunar samples of mantle origin. The existence of this ancient huge basin had been recognized since the late 1970's (2), but the Clementine laser altimeter characterized the full dimensions of SPA and showed it to be 2500 km in diameter and more than 8 km deep (3, 4). As the largest confirmed basin on the Moon (and perhaps the largest in the Solar System) SPA certainly holds promise for excavation through the crust and into the mantle. The mineralogy of the crust and upper lunar mantle has been estimated by several authors and for comparison we have used the 5-color multispectral UVVIS camera on board the Clementine mission (5) to perform a first-order evaluation of the mineralogy of SPA.

Source of SPA mafic component. Several possible sources or causes for the observed extensive mafic anomaly at SPA have been proposed (6, 7, 8), each with distinct mineralogical signatures. <u>Exposed Lower Crust</u>. There are geochemical arguments that the lower crust is more mafic than the anorthositic upper crust, and noritic in particular (9, 10), ie. containing low-Ca pyroxene. Plutons, the preferred source for the Mg-rich suite of crustal rocks (11), are also thought to concentrate in the lower crust. <u>Excavated Mantle</u>. Models for the mantle (12, 13), on the other hand, describe clinopyroxene, olivine, and pigeonite as the mafic minerals present in the upper part of the mantle, consistent with much of the multiple saturation experiments (14). According to the lunar overturn model (15), dunite forms the mafic cumulate below the lunar crust. <u>Melt Sheet</u>. Impact melt sheets are expected to have a larger relative volume for larger impact events (16) and the impact event would mix and perhaps homogenize the total melt. The melt sheet should thus, to a first order, represent the bulk composition of the strategraphic column involved in the melting event. If sufficiently large and thoroughly melted, the melt sheet itself may differentiate (17). <u>Cryptomare.</u> Since SPA is an ancient pre-Nectarian basin, it would be entirely possible that early volcanism filled much of the basin interior early and was subsequently covered by debris from later basin forming events. Such cryptomaria should exhibit a basaltic character, i.e., high-Ca pyroxene as the dominant mafic mineral.

Rock and soil types within SPA A carefully selected orbit of Clementine UVVIS data that begins exterior to the basin (10°S) and crosses into the center of the basin (60°S) at 182° longitude was calibrated, mosaicked, and processed to evaluate the mineralogy of SPA. Supplemental data also included in this analysis are several large craters with central peaks (see Tompkins and Pieters, these volumes), and two shorter mosaics (157° long., 20-40°S; 225° long., 60-70° S).

A summary of Clementine 5-color spectra of the rock and soil types observed in association with SPA is shown in Fig. 1. The three principal rock types found are <u>anorthosites</u> (largely exterior to the basin; identified by their lack of ferrous absorption), anorthositic <u>norites</u> (pervasive throughout the basin; identified by a low-Ca pyroxene absorption), and <u>basalts</u> (only associated with the small mare ponds [see Yingst and Head, these volumes]; identified by their high-Ca pyroxene absorption at longer wavelengths). Olivine-rich troctolite found at Copernicus and Tsiolkovsky, but notably absent in SPA, is shown for comparison.

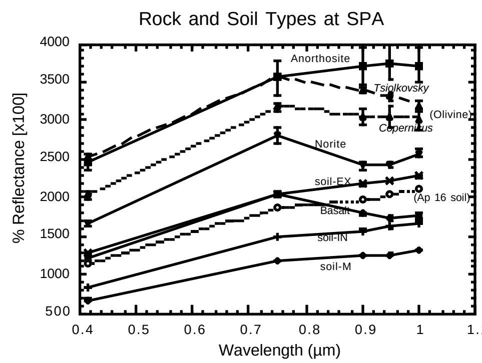

Figure 1. Representative 5-color spectra for rock and soil types found in the SPA region (solid lines). Low-Ca pyroxene indicating a noritic composition is readily recognized by the relatively short wavelength Fe^{2+} absorption. Similarly, high-Ca pyroxenes with a longer wavelength ferrous absorption are evident in the basalt ponds. Although no significant olivine was detected at SPA, spectra for the olivine-rich peaks of Copernicus and Tsiolkovsky are shown for comparison.

Highland soils exterior to the basin in the north are somewhat brighter than those of Apollo 16. This, coupled with the detection of abundant anorthosite, is indicative of the felsic (high Al, low Fe) composition of the topographically high terrain (3) north of SPA basin. The soils interior to SPA are darker and have a slightly stronger ferrous absorption, leading to the identification of SPA as mafic, or Fe-rich (1, 6, 7, 18). Soils developed on mare ponds within SPA are the darkest and often have somewhat stronger ferrous absorptions.

Freshly exposed material in SPA at both small and large craters (including central peaks) all exhibit the same general composition: anorthositic norite to noritic anorthosite. Five-color spectra for such areas, shown in Fig. 2, are remarkably similar and indicate low-Ca pyroxene is the dominant mafic mineral present throughout SPA basin. This pyroxene is also relatively abundant, and this same noritic composition is seen in all the parts of SPA studied. Although several areas may contain rock types with a mixture of two pyroxenes, no areas have been observed that are gabbroic in character (with high-Ca being the dominant mafic mineral), nor areas with abundant olivine (>30%).

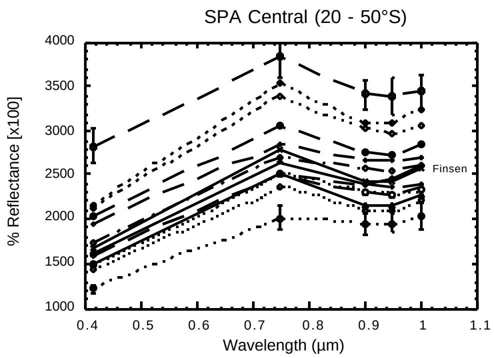

Figure 2. Five-color spectra of fresh craters of all sizes within South Pole-Aitken. Central peaks (of Finsen) are shown in solid lines. These spectra indicate low-Ca pyroxene is the dominant mafic mineral throughout SPA.

There are a few exceptions to the pervasive SPA norite: anorthosite is seen in a few rare cases within SPA. It is seen in a NW ring of Ingenii basin, not far from the estimated edge of SPA. The most perplexing occurrence is the anorthosite in the south wall and ejecta of the 75 km crater Alder located in the central part of SPA basin. Spectra for this region are shown in Fig. 3. The east wall and some of Alder central peaks exhibit the diagnostic features of a noritic composition, but most of the entire south wall and one central peak is anorthosite and void of significant mafic minerals.

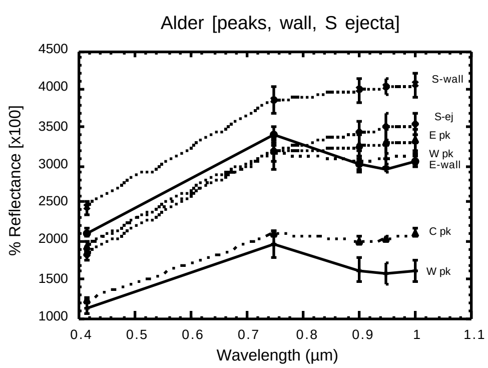

Figure 3. Five-color spectra for areas in and around the 75 km crater Alder. While abundant low-Ca pyroxene is found in the walls and central peaks, anorthosite is also found in the peaks, south wall and south ejecta.

Interpretations & Implications The prominent transition from a very anorthositic composition just exterior to SPA to a very pyroxene-rich (noritic) rock type on the interior of SPA suggests the original upper crust at SPA has been stripped away. This is consistent with the thin remaining crust at SPA modeled by geophisical data (3, 19). The lack of significant olivine or high-Ca pyroxene lithologies detected within the basin implies no mantle outcrops have been directly observed and little, if any, mantle has been excavated. No extensive basaltic cryptomaria have been detected, although the small mare ponds emplaced later are basaltic in character.

The uniformity of the noritic composition observed throughout SPA has several important implications. Since the same homogeneous rock type is seen in craters a few km in diameter as well as craters as large as Finsen (~85 km), there appears to be no significant vertical nor horizontal compositional variation across this huge basin. The pervasive SPA noritic rock type can be interpreted as (1) an extensive homogenized melt sheet, (2) a very homogeneous noritic lower lunar crust, or (3) some combination of the two.

If the interior of SPA is a huge melt sheet, then it has not differentiated into compositional layers and must represent the bulk character of the material melted. We interpret this to be predominantly lower crust. Equally consistent with the data, however, would be a very homogeneous noritic lower crust, brecciated and exposed by the SPA impact event. The third option, a homogeneous melt sheet overlying remnant lower crust of the same composition, may be the most realistic and accounts for the vertical and lateral scale of the homogeneity. Possible evidence for the edge of the melt sheet is a dark mafic-rich zone a few hundred m thick seen within the wall of the crater DeVries (50 km), which lies just within SPA basin at 20°S.

The occurrence of a significant zone of anorthosite 10's of km in dimension in the center of SPA is an enigma, reminiscent of the anorthosite discovered in the central peaks of Aristarchus (20), and serves as a reminder that there are numerous complexities yet to be resolved for this enormous basin.

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